Electrobioreactors AM Breakout Session

Emerging Ideas Workshops

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What approaches offer the greatest opportunity?

- Flow design cost in larger system
- *Electrode development?*
  - Increasing ohmic resistance, need better current collectors
- *Microbial coatings?*
  - Can the coating increase the # viable cells/m^2
  - Does coating increase current loss/efficiency
- *Increasing surface area to volume ratio?*
  - Diminishing returns with pure m^2/m^3 play due to matl cost
- *Improving material lifetime, stability, and reducing degradation?*
  - Ability to recharge microbe or reactor quickly (refresh step)

- \$/m^2 is a limiting factor for reactor scale-up
- Accurate (if possible) mass balance calculations are necessary

What is the ultimate system for delivering electricity to an electrobioreactor? Within an electrobioreactor?

- Cannot have microbial anode because electrolysis occurs at anode (O_2 generation) and efficiency
- Lost current efficiency is heat
  - Low efficiency creates issues for heat removal
- Why not CH_4-producing electrobioreactor to create low cost energy storage of alternative energy (non-domestic potential)

How would bioreactor designs change if this electricity delivery system was possible? What steps are necessary to deliver >1×10^6 Amps (>10 BOE/day) into a bioreactor? What power electronics, materials, and thermal management strategies are necessary?

- At large scale, ohmic losses kill efficiency
- How can reactor achieve single connection of nodes across large system (1 wire input to whole system)
- Microbe attachment dependent (how they connect to grid)
- Could you have a flow or fuel cell type battery with electrode being the current source (rest phase away, active phase touches current source)
- Thermal: no, water management issue trumps heat

What is the optimal way to deliver and remove gases to these systems?

- Increase H_2 delivery through bubbles? Alternative chemicals? bubble stability surfactants? due to limited water solubility
- Need to reduce gas back pressure
- Bio-mimetic type systems (dynamic)
- Higher m^2/m^3 systems would require radical delivery methods ("gas highways")
- Spinning reactors to create thin fluid flow?
  - See "Process Intensification"

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Can these reactor systems be stably operated for week, months? How can one design to avoid contamination? What are the major contaminants?

- What are forces on organism over long-periods of time determine lifetime
- What is rate limiting step origin (biological or mass transfer or electronic current delivery?)
- O_2 fouling of anaerobic system
- Isolation of contamination (reduce product cross-over)
- Biocathode long-term stability? As bioanodes are more stable
- Separate systems would reduce contamination, but reduce flow efficiency
- What are minimum nutrients needed over long-term to support biocathodes (at scale, demonstration of biocathode startup consistently)

Key take Aways

- Electrode cost ($\$/m^2$), associated ohmic losses by m2, and pH stability
- Mass transport in large system
- Long-term performance
- Need to achieve 100+ A/m^2 on cathodes to produce significant product per surface area
- Final electrode structure feature size must fit organism and flow
  - Biomimetic structures (e.g. lungs) may approach the ideal
- System flow modeling is important
- Product dependent design (gas vs. liquid, soluble vs. insoluble)

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Where is the ARPA-E white space? What are the high level techno-economic metrics necessary for commercial adoption? What detailed performance metrics are necessary for success?

- Connect Electrofuels program results to an engineered system
- Define a minimum surface area productivity (>10^{-6} mol/cc-s)…SOA: 550 mmol acetate/m^2-day.
- Define a minimum kWh/L production
- Maximum productivity of product/dry weight
- Biofilms that can operate at higher current densities
- Focus on increasing production rate (e.g. 10x)
- System lifetime to determine ROI

What can be done with $3-4M, 2-3yrs?

- ARPA-E must define surface area/volume or deliverable reactor size
- Defined metric vs. Open ended FOA
- Seedlings grants needed to better define fundamentals before applied system-level approach (identify and solve the correct problem)

What advances/breakthroughs (if any) have there been in the last 10 years that might make this possible now?

- Unknown. Field is too immature.
- Better follow up support of ARPA-E projects that need more basic science from both DOE and other organizations

Next Steps

- Order of magnitude increase in productivity **OR** focus on electrode spacing in order to scale up
- With proper team-building basic questions could be answered